MASS SPECTROMETER AND MASS FILTERS THEREFOR

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue; a claim printed with strikethrough indicates that the claim was canceled, disclaimed, or held invalid by a prior post-patent action or proceeding.

PRIOR APPLICATIONS

This application claims benefit of Patent Cooperation Treaty Application Number PCT/GB03/02041, filed May 13, 2003, which claims priority from Great Britain Application Number 0210930.4, filed May 13, 2002.

TECHNICAL FIELD

This invention relates to a method and apparatus for improving operational characteristics of mass spectrometers.

The invention is described herein with reference to quadrupole mass filter arrangements, but is not limited to such apparatus.

BACKGROUND

Quadrupole, or multipole mass filters are known in the mass spectroscopy art and operate to transmit ions having a mass/charge ratio which lie within a stable operating region. The size of the stable operating region is governed by the geometry of quadrupole rods, and the magnitudes of DC and RF voltages (including the RF voltage's frequency) applied to the rods, amongst other factors. Thus, the transmitted ions can have a range of mass/charge ratios depending on the size of the stable operating region. The transmission characteristics of the filter, and hence the range of mass/charge ratios within the transmitted, or filtered ion beam, can be reduced by reducing the stable operating region's size. Rejected ions are not transmitted to the spectrometer's output or detector.

A substantial proportion of the rejected ions strike the quadrupole rods sputtering material from, and/or depositing dielectric material onto the rods. A large amount of deposition can occur over time, particularly when a spectrometer is used to analyse masses of particles within relatively intense ion beams. Deposited material can result in areas of the rod's surface becoming partially or completely insulating, or having a different electrical work function. Thus, the material deposited on the rods affects the characteristics of the electric field associated with the voltages applied to the rods. Ultimately, the deposited material changes the electric field strength near the surface of the rods.

A further problem, known as the space charge effect, occurs when analysing relatively intense ion beams. As the intense ion beam enters the quadrupole mass filter the electric field associated with the voltages applied to the quadrupole rods is distorted. This distortion of the field is due to the presence of the charged particles in the ion beam. The electric field distortions occur in the vicinity of the ions in the beam.

Quadrupole mass filters are seriously affected by these problems, particularly when a spectrometer comprising such filters operates at a high mass resolution. Very onerous demands on the precision with which the electric field is maintained are required for high resolution mass spectrometry. Furthermore, at high resolving powers, the stable trajectories of ions through the filter pass very close to the rods for relatively long distances in the filter. Therefore, the trajectories pass very close to the deposited dielectric material, and hence within a region of the electric field suffering from distortions.

Also, the resolving power of a spectrometer is approximately proportional to the square of time spent in the filter by the ions. Thus, a desired resolution may only be achieved if the ions spend sufficient time in the filter; the longer the ions spend in the filter, the greater the resolution obtained. It is usual to decelerate the ions to very low energies (typically 2 ev) to maximise time spent in the filter, and hence increase resolving power of the spectrometer. The space charge effect is high for such a slow ion beam, and this exacerbates the problems associated with distorted electrical fields caused by the space charge effect. Thus, presently there is a compromise between the space charge effect, ion beam energy and spectrometer mass resolution.

A mass filter having a distorted electric field caused by the problems described above can have a considerably reduced mass resolving power or transmission. In the worst case, the spectrometer is rendered useless. The problems are exacerbated over time as more dielectric material is deposited on the rods. The accumulation of material tends to be uneven with more material deposited close to the entrance of the filter since most ions are rejected on entry into the filter. When the spectrometer's performance falls below a tolerable level it is necessary to replace or refurbish the mass filter at considerable cost.

U.S. Pat. No. 3,129,327 discloses auxiliary electrode rods which are driven only by AC voltages to improve transmission into a second set of rods which act as a mass filter; the auxiliary electrodes act as an ion guide.

U.S. Pat. No. 4,963,736 discloses a rod set operating with substantially no DC voltage and at an elevated pressure. Thus, the filter act as a pressurised ion guide which has high transmission properties due to collision focussing.

U.S. Pat. No. 6,140,638 discloses a mass filter comprising a first filter operating as a collision/reaction cell and at an elevated gas pressure with respect to a second filter. The apparatus disclosed aims to reduce isobaric interferences by transmitting ions through a collision cell to reject intermediate ions which would otherwise cause isobaric interferences.

U.S. Pat. No. 6,340,814 discloses a spectrometer comprising two filters operating with similar mass resolution to improve the resolution of the whole device. When the two filters are coupled to one another, a higher resolution is achieved compared to the resolving power of each filter separately.

EP1114437 discloses a method and apparatus for removing ions from an ion beam to reduce the gas load on the collision cell which serves to minimise the formation, or reformation, of unwanted artefact ions in the collision cell.

None of these systems propose a solution to the problems described above.

SUMMARY OF THE INVENTION

It is an aim of the present invention to ameliorate the problems associated with the prior art. In their broadest form, embodiments of the invention reside in a mass spectrometer which comprises a multiple mass filter stage. In one of the mass filters a large proportion of unwanted ions are removed from the ion beam.

More precisely, there is provided a mass filter apparatus for filtering a beam of ions having mass/charge ratios in a range of mass/charge ratios to transmit ions of a selected mass/charge ratio in the said range, comprising an ion beam source